

Boundary Layer Processes in the Surf Zone and Inner Shelf in CROSSTEX and MISO

Timothy P. Stanton
Oceanography Department, Code OC/ST
Naval Postgraduate School
Monterey, CA 93943-5000
phone: (831) 656 3144 fax: (831) 656 2712 email: stanton@nps.edu

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<http://www.oc.nps.navy.mil/~stanton/>

LONG TERM GOALS

Long term goals are to observe and model turbulent stresses in the bottom boundary layer (BBL) arising from wave forcing and low frequency currents, and the resulting sediment transport, and bedform evolution in the inner shelf and surf zone. The presence of mobile sandy beds across continental shelves and surf zones results in complex interactions and strong feedbacks between fluid motion in the bottom boundary layer and sediment movement both as bed load and suspended sediment flux. A primary goal is to develop parameterizations of the formation of different bedform types to different aspects of wave and current forcing and to improve models of wave-forced sediment transport. The observations made in this project are being used to understand and model sediment transport and effective bed roughness and BBL wave dissipation in response to these evolving bedforms.

OBJECTIVES

A primary scientific objective of this project is to measure turbulent stresses, shear and sediment fluxes in the bottom boundary layer in both inner shelf and surf zone field experiments and large scale tank experiments. The field observations represent the more complex superposition of forcing factors including cross-shore and long-shore low frequency currents, and broad band wave forcing. These long term (months to years) timeseries provide a range of these forcing parameters. Inner shelf field BBL observations from the 12m depth cabled MISO observatory in Monterey bay and surfzone measurements from RIPEX and NCEX are being used in these analyses. Data sets from these field programs are being complimented by measurements using the same instrument systems deployed in the large scale wave flume at the OSU Hinsdale Large Scale Wave Flume during CROSSTEX in the fall of 2005. This provided an opportunity to measure the BBL under controlled, repeatable, programmable wave conditions with negligible longshore mean currents. This provided more constrained forcing conditions than achievable in the field allowing sediment transport processes to be more readily separated, and the opportunity to close sediment transport budgets.

APPROACH

A four beam Bistatic Coherent Doppler Velocity Sediment Profiler (BCDVSP) developed in my research group at NPS (Stanton 1996, 2001, 2006a) has been used to acquire a three month and 2 month BBL data sets at the MISO inner shelf site, and month-long surfzone measurements in

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Monterey Bay and Blacks Beach. Bedform maps were measured every 15 minutes using a scanned altimeter with 2cm horizontal and 0.2cm vertical resolution in a 1m square area surrounding the 0.8m high profile of 1cm binned 3 component velocity vectors measured by the BCDV. A 5 beam version of the BCDVSP, that provided additional symmetry in the stress calculations and redundant velocity component sampling, was deployed for a 3 week period in the OSU flume s during the CROSSTEX (figure 1). A new scanned laser imaging system was used to rapidly measure small scale bedforms and cross shore sediment suspension structure at 30 Hz rates and 2mm scales during this experiment (figure 2). The same 2 axis scanned laser also mapped small scale bed morphology to 2mm scales at a 0.5 Hz rate over a 0.5m square, capturing the 3D structure of suborbital ripple formation and transitions to sheet flow in higher forcing conditions.



Figure 1. A view of deployed instruments looking down the sand beach (at “low tide”) within the OSU Large wave Flume during CROSSTEX. The left spar supported the 5 beam BCDV velocity and suspended sediment profiler, the acoustic scanned altimeter, and the scanned laser. The right spar suspended a reference ADV current sensor and camera that imaged the bedforms and scanned laser patterns.

During CROSSTEX, the 104m long wave flume was used to produce primarily sets of TMA γ_{10} waves spanning a forcing matrix of 0.3, 0.4, 0.5 and 0.6m nominal wave height over a range of 4, 6 and 8 s peak periods. These 15 minute duration wave sets propagated toward a natural sand beach that was maintained (through broadband wave choices) as a single barred beach. This hierarchy of bed stress and orbital diameter allowed sediment suspension events and net transport to be measured and the concurrent bedform evolution during each run to be quantified. Narrow band wave cases were

limited in duration to prevent strong seiche modes and rapid bar formation, and were interspersed with longer wide-band runs to restore uniform beach conditions.

WORK COMPLETED

Calibrations and data processing of the BCDVSP profiler has been completed allowing concurrent velocity and sediment profiles to be derived for each run. Analysis of a series of *in situ* sand samples from the two measurement locations has shown a well sorted sand distribution with negligible variation in time through the 2 week experiment, increasing the accuracy of the *in situ* – based acoustic backscatter calibration used to calculate sediment concentration profiles. Two BCDVSP backscatter calibrations taken from the start and end of the experiment resulted in very close calibration fits. Processing of the scanned laser morphology maps is in progress, and completed for the clearer water cases. Software to readily access the many components of the data set for each run has been completed. Analysis of 3 wave forcing cases is looking at differences in bedform evolution and sediment transport at the low slope offshore location and the higher slope, larger scale morphology inner location on the offshore side of the bar, under identical forcing conditions.

RESULTS

The first analysis of CROSSTEX is focusing on factors controlling sediment suspension under shoaling waves offshore of the bar (Stanton, 2006a). The high temporal and spatial resolution cross shore scanned laser imaging system shows the rapid evolution of sub orbital ripples within the strongest wave groups, while the BCDVSP quantifies the bed stress and net suspended sediment flux through the water column (Figure 2). Comparisons are made with several current sediment transport models. On-going analyses are using 1D $k-\omega$ models forced by u_∞ to compare with the observed BBL structure. The shortest period wave runs will also be used to compare with very high resolution sediment mixture models being run by Don Slinn and Tyler Hesser.

Techniques to estimate stress profiles in combined mean current and oscillatory flows from field data with data dropouts due to bubble clouds and other scatterer effects are being developed for the inner shelf and nearshore data sets (Stanton 2006b). Scanned altimeter data and wave forcing from a year-long timeseries at the MISO site are being combined with two more detailed MISO data sets with BCDVSP profiles to determine hydrodynamic forcing conditions in the bottom boundary layer as relict bedforms are left after as strong wave forcing events end (Stanton 2006c). In a separate effort, 2 week-long data sets taken from Duck NC and the MISO site have been found where a wave-forced lutocline is advected to the the measurement site where it remains as a 5 – 10cm fluidized layer above the fixed bed following string wave forcing events. An analysis of the wave forced lutocline coupling and resulting surface gravity wave dissipation is in progress.

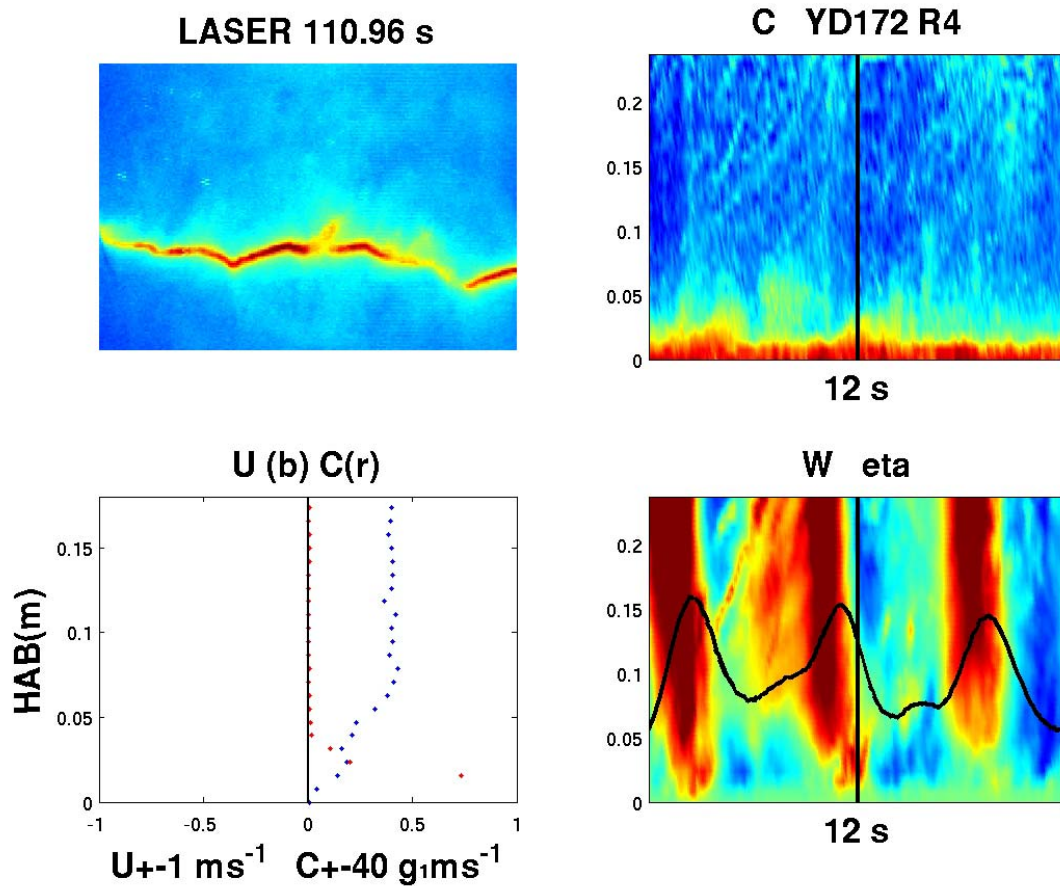


Figure 2. A single frame of a 20 Hz sampled time sequence of bottom boundary layer observations made at CROSSEX and 0.4m nominal wave height 4s period waves. a.) The scanned laser false color image representing the cross-shore sediment suspension vertical structure, with suspension events seen along the crest of the small sub orbital ripples. The cross shore scale is 0.4m. b.) The corresponding suspended sediment concentration profile time series above the bed. c.) The instantaneous cross shore current (blue) and suspended sediment concentration (red) profile. d.) The vertical velocity profile time series (saturated red is +5 cm/s) with the wave height time series superimposed. These concurrent time series show the detailed structure of the sediment suspension events, while wave phase analyses averaged over the whole 15 minute runs are used to measure net fluxes, and the relationships between instantaneous stress and wave induced pressure effects.

IMPACTS / APPLICATIONS

Improved understanding of wave and current forcing and bedform response are critical to improving high resolution wave models for coastal areas. Bedform prediction and sediment transport models are being improved with these data sets. The detailed hydrodynamic measurements through the mean current and wave boundary layers provide estimates of wave work rates over the evolving bedforms, allowing parameterizations for these complex processes to be developed.

RELATED PROJECTS

This research is coordinated with the NCEX nearshore canyon project, and the Ripples DRI. Analysis of the CROSSTEX data sets is underway in collaboration with Diane Foster, Tom Hsu, Don Slinn and other CROSSTEX colleagues. This work is also being extended with NSF-sponsored participation in a benthic flux program in collaboration with colleagues at the University of Hawaii.

TRANSITIONS

Improved ripple / BBL parameterizations will be transitioned into high resolution nearshore models including Delft3D and ongoing model community models.

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